Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

COMMENTS OF QUALCOMM INCORPORATED

Dean R. Brenner
Senior Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

January 25, 2013

SUMMARY

Qualcomm appreciates this opportunity to provide comments on the *Incentive Auction NPRM*, which is a critical piece of the FCC's multi-faceted efforts to free up much-needed spectrum for mobile broadband. As a leading developer of wireless technologies and chipsets that are fueling the ever-increasing demand for mobile broadband here and abroad, Qualcomm's comments focus on providing technical input to assist the FCC in developing a 600 MHz band plan to ensure that the incentive auction is a success and that the repurposed spectrum is quickly and efficiently put to use for mobile broadband. These comments are based upon a substantial amount of foundational engineering analysis on 600 MHz mobile broadband operations that Qualcomm has conducted to date. As this proceeding continues, Qualcomm will continue its technical work and continue to work closely with all interested stakeholders in an effort to reach consensus on as many of the technical issues as possible.

Based on our analysis to date, we recommend that the FCC adopt a band plan that: (a) maximizes the amount of licensed spectrum made available through the clearing and repacking processes; (b) avoids interference to and from licensed wireless services; (c) enables mobile device performance and size comparable to today's smartphone and tablets; (d) minimizes the cost of devices and device components (such as antennas, duplexers, etc.); and (e) provides paired spectrum blocks as well as blocks for supplemental downlink ("SDL") that are fungible and can support both carrier aggregation and standalone deployments. A 600 MHz band plan that meets these objectives will maximize the value of the auctioned spectrum, enable the spectrum to be quickly put to use, and thus help to satisfy, in part, the nation's critical need for additional mobile broadband spectrum, which is the core goal of this entire undertaking.

In line with these objectives, Qualcomm believes that the Commission should adopt a 600 MHz band plan that provides as much licensed paired spectrum for mobile broadband use as

possible. To the extent the FCC recovers additional spectrum — beyond the spectrum that best supports FDD (*i.e.*, Frequency Division Duplex) operations — Qualcomm recommends that such spectrum be used for licensed SDL.

In light of these goals and the technical realities of wireless technology — specifically the RF filters and duplexers expected to be available by the end of 2014 (after the auction is projected to end and the spectrum can begin to be used for mobile broadband), and the antenna constraints described herein, which are not expected to change over time because they remain bound by the laws of physics — Qualcomm is most confident about the technical feasibility of a 2 x 25 MHz FDD band plan similar to the FCC's so-called alternative band plan, in which the uplink is directly adjacent to the Lower 700 MHz A block, there is a 10 to 14 MHz duplex gap (a gap of approximately 11 to 12 MHz is preferred), and then the downlink band. Additional spectrum, over and above this 60 to 64 MHz, should be allocated and auctioned for SDL.

In contrast to the FCC's preferred band plan, which contains two guard bands (between TV stations and mobile broadband operations) and a duplex gap, a 2 x 25 MHz FDD band plan would include a duplex gap and only one guard band, thus providing a more spectrally efficient outcome. To the extent the FCC recovers more than 12 TV channels and enables the additional spectrum to be used for SDL purposes, a single guard band would exist between TV stations and supplemental downlink operations. Qualcomm believes that approximately 10 MHz of separation between the highest remaining full power TV station and the first supplemental downlink block will be sufficient to avoid saturation of the mobile device receiver, but 6 MHz of that separation may be provided by Channel 37 (on which the existing operations could continue). In that case, the actual guard band could be greatly reduced to approximately 4 MHz.

Also, it should be possible to reduce the separation to less than 10 MHz if the highest TV station abutting the downlink block is a low power TV station (operating at 50 kW or less).

A more technically challenging FDD band plan that Qualcomm is studying for feasibility is a 2 x 30 MHz configuration with a 10 MHz duplex gap. Qualcomm believes that this band plan would require two duplexers to implement. To have any chance of feasibility, such a plan could include a duplex gap no larger than 10 MHz because of antenna bandwidth issues, which again are constrained by the laws of physics. Indeed, using a 70 MHz operating bandwidth on a single antenna system may be well beyond the upper bounds of technical and practical feasibility in a smartphone form factor. We are more confident about the feasibility of the plan with 2 x 25 MHz and a duplex gap of 11 to 12 MHz because the antenna operating bandwidth in that case would not exceed 62 MHz.

We believe it is important to strive to develop a 600 MHz band plan that will enable use of a single antenna system (*i.e.*, permitting re-use of an existing antenna system in today's devices that support 700 MHz), rather than a plan that will require adding an additional antenna system because there is not enough space for another antenna system in today's smartphones. Our concern is that adding another antenna system will require smartphones to become unacceptably larger or not perform acceptably. Using a single antenna for 600 MHz will require an antenna tuner, and particularly with regard to this challenging 2 x 30 MHz / 10 MHz duplex gap band plan, we believe it would be extremely difficult to develop a solution that carriers, vendors, and consumers will find acceptable.

Moreover, the lowest 5 MHz spectrum block on the uplink side of this band plan (that is, the sixth 5 MHz block below Channel 52), would introduce a fourth order harmonic that could potentially interfere with BRS/EBS (Band 41) operations in the 2.5 GHz BRS/EBS band; adding

the sixth 5 MHz block to the uplink also introduces substantial risks of increased intermodulation distortion ("IMD"). In other words, were the FCC to adopt a band plan with a sixth 5 MHz uplink block immediately below Channel 52, operations in that block may interfere with 2.5 GHz operations and also face antenna challenges, so that block would not be fungible with (*i.e.*, be spectrally equivalent to) the other blocks. Thus, the technical issues with implementing a band plan with more than the highest five 5 MHz uplink blocks appear significant.

Uplink operations in the lower portion of the 600 MHz band (*i.e.*, below the fifth 5 MHz block below Channel 52), are potentially troublesome because they would introduce lower-order harmonics and significantly greater levels of IMD that may cause interference to other mobile bands used in today's smartphones and tablets. In addition, this plan could result in interference that could also impair position location performance in devices. Thus, uplink operations in this lower portion of the band may not be spectrally equivalent to (and thus be worth less than the spectrum used for) uplink operations at the top end of the 600 MHz band. In addition, creating a second FDD pairing would require additional filters, an additional sizeable antenna, and a second duplex gap and thus reduce the amount of overall usable spectrum.

Qualcomm does not support the FCC's proposed approach of placing downlink operations below TV Channel 37 (which are paired with uplink operations directly adjacent to the Lower 700 MHz A block) because it would create an extremely wide operating bandwidth that cannot possibly be supported via a single antenna in a smartphone form factor, which is highly preferred given today's space-constrained devices. We believe that a national band plan that frees up as much spectrum as possible for mobile broadband along the lines of what we describe herein is more feasible and will more likely lead to successful implementation. Every effort should be made to accomplish a national plan through repacking alone and through the

auction itself and subsequent repacking. Qualcomm realizes, however, that the realization of a national band plan may be challenged in regions where significantly less spectrum is freed up, such as in border areas. In those areas, the FCC should consider the feasibility of keeping the amount of downlink spectrum constant and implementing a 5 or 10 MHz uplink band. We describe herein how to do so without causing interference to mobile devices, for interference from wireless base stations to adjacent channel TV stations must also be considered. A national plan would avoid any such issue.

To ensure that the FDD blocks adjacent to the duplex gap are spectrally the same as the other blocks that are 5, 10, 15 MHz away from the duplex gap, our initial analysis indicates that there should be no unlicensed TV white space devices, wireless microphones, or SDL operations within the duplex gap. Not only could mobile operations in directly adjacent bands be negatively impacted by duplex gap operations, but these operations themselves also may be negatively impacted by 600 MHz mobile operations. Nonetheless, should the FCC decide to place some operations within the duplex gap or lower guard band, wireless microphones are much preferred because their geographically-contained operations likely will pose far less pervasive interference than TV white space devices. Placing SDL operations in the duplex gap will widen the gap because of the guard band necessary to protect the downlink from the uplink, and a wider duplex gap introduces antenna issues (along the lines discussed above) and thus would detract from the total amount of paired spectrum. Our concerns with operations in the duplex gap apply also to operations in the guard bands between TV stations and the downlink bands mentioned above.

As this proceeding continues, Qualcomm will continue performing technical work on 600 MHz and will provide additional input to the Commission and other stakeholders. As this analysis proceeds, we may have refined conclusions about the technical issues discussed herein.

CONTENTS

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

COMMENTS OF QUALCOMM INCORPORATED

QUALCOMM Incorporated ("Qualcomm") is pleased to comment on the Commission's historic *Incentive Auction Notice of Proposed Rulemaking*.[1] The successful design and execution of the world's first incentive auction — wherein television broadcast licensees are induced to voluntarily relinquish their current spectrum rights via a reverse auction in exchange for payment from the proceeds of a forward auction of new spectrum licenses that are critical to supporting ever increasing mobile broadband demands — will be one of the most complex undertakings in the history of the FCC.[2] For this proceeding to be successful, the FCC must develop rules and a future band plan that provides as much clarity and certainty as possible to current broadcast licensees and to future flexible use licensees, *see NPRM* at ¶ 123, to encourage the highest levels of participation from both groups and for the agency and America to reap the greatest value.

---

1 *See* Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Notice of Proposed Rulemaking*, FCC 12-118 (rel. Oct. 2, 2012) ("*Incentive Auction NPRM*" or "*NPRM*"); *see also* Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Order*, DA 12-1916 (Nov. 29. 2012) (extending comment date to January 25, and reply comment date to March 12, 2013).

2 *See, e.g.*, Statement of Commissioner Robert M. McDowell (this is "*the most complex spectrum auction in world history*") (emphasis in original); Statement of Commissioner Jessica Rosenworcel ("Simplicity is key. Incentive Auctions are an undeniably complex undertaking.").

As a leading developer of mobile broadband chipsets and technology that is fueling the mobile broadband revolution, Qualcomm's comments focus on providing technical input to assist the Commission in the technical design of what we hope will be the optimal 600 MHz band plan for the forward auction, so the FCC can maximize the value and use of the newly freed up licensed spectrum for mobile broadband. As the Commission appropriately recognizes, because the amount of spectrum recovered via the reverse auction will vary from location to location across America, the agency may need to employ a flexible approach that supports an "accordion" of band plans.[3]

Given the highly complex nature of the simultaneous and tightly interrelated reverse and forward auction processes[4] (which have never before been carried out anywhere in the world) and because those participating in the forward auction will not know the specific frequency range of the spectrum blocks on which they will place bids (another novel aspect of this pioneering incentive auction), it is critically important that the FCC offer at auction paired spectrum blocks that are effectively identical from an interference perspective, and thus fully fungible. And, to the extent the FCC offers additional spectrum blocks that can be used to support supplemental downlink ("SDL") operations, the agency likewise must ensure that such blocks are spectrally identical from an interference perspective, and thus fungible. The 600 MHz band plan should account for the expected use of LTE technology and use in conjunction with existing wireless networks.

---

3 *See Incentive Auction NPRM* at ¶ 8 ("Instead of a single band plan with identified frequencies, a set number of spectrum blocks and a uniform set of geographic area licenses, the auction design must provide a framework that is flexible enough to accommodate varying amounts of newly available spectrum in different locations."); *see also id.* at ¶ 123.

4 *See Incentive Auction NPRM* at ¶¶ 5, 36.

Because it is critically important that the spectrum repurposed via the incentive auction process be placed online as soon as possible, Qualcomm's comments are grounded in determining how best to incorporate the 600 MHz spectrum into existing smartphone and tablet form factors and are based upon device components (such as filters, duplexers, tuners, and antenna systems) that we reasonably expect to be made available over the next 18 to 24 months, when the repurposed spectrum is expected to be placed online.[5] It is crucial that the Commission not adopt a band plan that relies upon components that are unlikely to be available next year, when the spectrum will be auctioned. To do so would impair the value of the spectrum and pose a substantial risk that the auction will be unsuccessful.

Not all band plans lend themselves to being readily incorporated into smartphones and tablets without increasing the cost, form factor, power consumption, and overall complexity of the devices. In our view, adoption of a sub-optimal band plan would pose implementation difficulties for the wireless industry, and it may lead to lower bids from forward auction participants. A successful band plan design is one that could be readily incorporated into wireless devices that are comparable in size and function to the devices that consumers heavily use today. Such a band plan would ensure that auction winners can rapidly deploy services on the new spectrum and, like today's devices, support simultaneous operations using multiple technologies in multiple bands. This will cause 600 MHz forward auction bidders to not

[5] While it is possible to imagine that band plans other than those that Qualcomm recommends could be implemented, such plans are likely to increase the size, cost, and battery demands of mobile devices that include the 600 MHz band for these devices would need additional duplexers, filters, antennas, and switches to the extent they support 700 MHz, cellular, and other mobile or positioning bands. Implementing such band plans also may depend upon technology that does not exist today and is not under development. In either case, it would be unwise to adopt any such plan.

discount their bids, but instead enable the auction to become the Commission's most successful auction ever on a $/MHz/Pop basis.

It is within this framework — that is based upon and fully consistent with the FCC's core goals[6] — that Qualcomm has done its technical work and analysis relating to the 600 MHz band plan options proposed in the *Incentive Auction NPRM*.

DISCUSSION

I. Qualcomm Believes That A 2 x 25 MHz FDD Band Plan With A Narrow Duplex Gap Similar To The Plan Proposed In Figure 12 Of The *Incentive Auction NPRM* Is Technically Feasible And Can Be Successfully Implemented

Based on its technical analysis to date of potential 600 MHz band plans, Qualcomm believes that a 2 x 25 MHz Frequency Division Duplex ("FDD") band plan with a narrow duplex gap (*i.e.*, approximately 12 MHz) that is similar to the plan set out in Figure 12 of the *Incentive Auction NPRM* as shown below is technically feasible and can be successfully implemented because it can be readily incorporated into today's mobile devices and minimize device size, complexity, and cost.

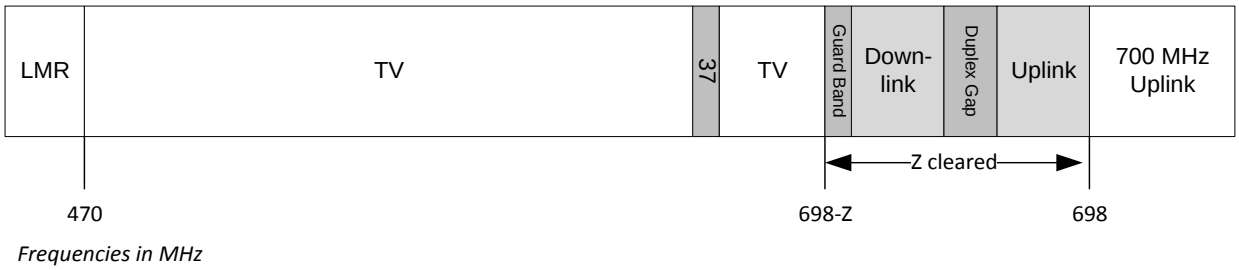

Figure 12 in *Incentive Auction NPRM*. Alternative Approach, Down from Channel 51

[6] *See Incentive Auction NPRM* at ¶¶ 123-24 ("[T]he band plan must provide as much information and certainty as possible, to enable interested wireless providers to make informed business decisions about whether, and how, to bid for and use 600 MHz spectrum. … [A] band plan that balances flexibility with certainty, accommodating varying amounts of available wireless spectrum in different geographic areas [will help to] ensure as a technical matter that wireless providers [can] offer mobile devices that can operate across the country, … minimize device cost and interoperability concerns, and allow for greater economies of scale.").

The FCC's proposed collection of band plans that place the downlink band below Channel 37 and maintain TV stations in the duplex gap above Channel 37 (as depicted in Figures 4 through 10 of the *Incentive Auction NPRM*) are far from optimal because they require the use of two extended guard bands to limit interference between high-powered TV broadcast operations and 600 MHz mobile broadband operations. Band plans that require such extended guard bands would unnecessarily limit the amount of spectrum that can be repurposed and auctioned for mobile broadband purposes.[7] These sub-optimal band plans also require a large passband that cannot possibly be supported via a single antenna system. We believe that the auction is most likely to be successful if the 600 MHz band plan is designed such that it can be readily incorporated into existing devices that currently support multiple bands and are already extremely size limited. Thus, Qualcomm agrees with the FCC that the band plan needs to provide 5 MHz spectrum blocks that "are as similar and technically interchangeable as possible to allow for enhanced substitutability across blocks."[8]

In evaluating the FCC's proposed band plans, Qualcomm analyzed numerous technical aspects, including the impact that harmonics from 600 MHz uplink signals would have on other higher band operations (including sensitive positioning bands) that may be in use on the same mobile device, such as a smartphone or tablet, and for Carrier Aggregation ("CA").[9] Concurrent support for multiple bands is a common feature and central to offering CA, which enables significant capacity enhancements.

---

7 Allowing standard 1 MW TV broadcast operations band in the middle of a land mobile downlink would likely require 12 MHz of guard band between the TV and each downlink band based on information from filter vendors to date.

8 *Incentive Auction NPRM* at ¶ 152.

9 Most wireless operators in the U.S. and abroad are planning to deploy CA technology, which is in the LTE-Advanced standard. CA allows an operator to build a bigger mobile broadband pipe by bonding together two spectrum bands to create one wider band for operations.

Qualcomm's harmonic analysis, which is described in Section I.A below, shows that the uplink portion of the 600 MHz band is best placed directly adjacent to the Lower 700 MHz uplink band, like the Commission provided in each of its proposed band plans.[10] Qualcomm's harmonic analysis and its Intermodulation Distortion ("IMD") analysis both show that it would be particularly challenging to support a 600 MHz uplink band that extends beyond 25 MHz in mobile devices that also support bands above 600 MHz, like virtually all of today's smartphones and tablets.

Next, as described in Section I.B below, Qualcomm examined the frequency response and available instantaneous bandwidth of candidate antenna technologies, including the retuning of existing antennas in mobile devices, and determined that the laws of physics make it essentially impossible to support (via a single 600/700 MHz antenna system) an operating bandwidth (or passband) larger than 70 MHz, that is, a 30 MHz uplink band paired with 30 MHz downlink band coupled with a (sub-optimal) 10 MHz duplex gap. In fact, it is just not clear today whether a single 600 MHz antenna system can efficiently support an operating bandwidth as wide as 70 MHz. Thus, the band plans shown in Figures 4 through 10 of the *Incentive Auction NPRM* — where the downlink spectrum is located below Channel 37 and paired with uplink spectrum that is directly adjacent to the Lower 700 MHz band — cannot be supported via a single antenna system (as is the case with mobile operations in other bands) because the required instantaneous antenna bandwidth, which exceeds 100 MHz, is too great. Adding an additional antenna into smartphones and tablets to support this band increases device size, complexity, and cost, and thus introduces potentially insurmountable design challenges given consumer demand for wireless devices with smartphone-sized form factors.

---

[10] *See generally Incentive Auction NPRM*, ¶ 126, Figures 4 to 15 and associated text.

Additionally, as explained in more detail in Section I.C below, to the extent the FCC recovers more than 12 TV broadcast channels (that is, more than 72 MHz) to auction for flexible use, the agency should allocate those spectrum blocks for SDL application.[11] These downlink bands may need to be paired with spectrum above 1.7 GHz due to antenna considerations.

While certainly not preferred (but recognizing that it may occur), in areas where the FCC recovers fewer than 12 TV broadcast channels, the FCC should maintain, to the extent possible, the same 25 MHz downlink portion within the same frequency band as in the areas where it recovers 12 or more TV broadcast channels, and should allow low power TV stations to reside within the duplex gap with adequate guard bands. In these areas, the plan may provide for 5 or 10 MHz of uplink spectrum, as explained in Section I.D below.

Thereafter, Qualcomm presents its initial assessment of whether the duplex gap or guard bands should be used for TV white space devices or wireless microphones, and last, Qualcomm reviews and generally supports the proposed technical rules for 600 MHz mobile operations.

A. Analysis Of 600 MHz Signal Harmonics As Well As Intermodulation Products Shows That The 25 MHz Spectrum Block Directly Adjacent To The Lower 700 MHz Band Is Best Suited To Support Uplink Operations

Qualcomm analyzed the signal harmonics and intermodulation distortion ("IMD") generated by 600 MHz band transmitters that potentially would impact concurrent mobile operations in higher bands. In performing its analysis of signal harmonics, Qualcomm divided the 20 TV broadcast channels that span 578 to 698 MHz, *i.e.*, TV Channels 32 to 51, into 24 analysis blocks of 5 MHz each, as shown in Figure 1 below.[12]

---

[11] *See Incentive Auction NPRM*, ¶¶ 131, 133.

[12] Qualcomm supports the Commission's proposal to license the 600 MHz spectrum, both paired FDD and unpaired downlink operations, in 5 MHz building blocks. *See Incentive Auction NPRM* at ¶ 128.

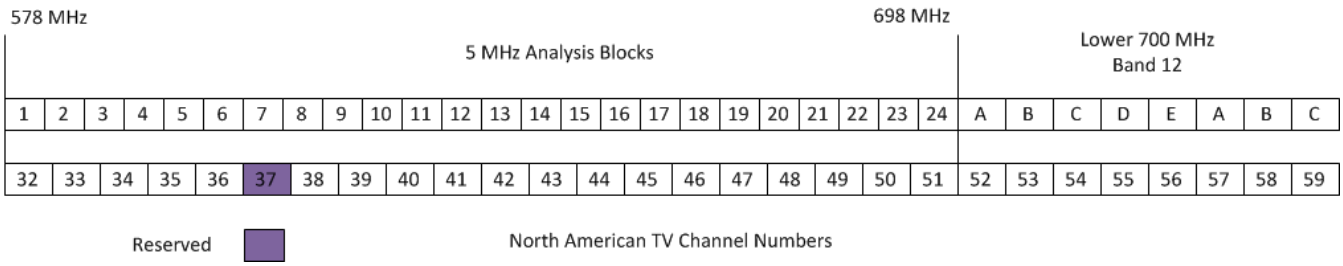

Figure 1. TV Broadcast Channels 32 to 51 Analyzed As Twenty-Four 5 MHz Analysis Blocks

Interference from the harmonics of a transmit signal is caused by non-linear characteristics inherent to the output stages of transmitters. The harmonics are integer multiples of the transmitted signal (*e.g.*, a 695 MHz signal has a second order harmonic at 1390 MHz, a third order harmonic at 2085 MHz and so on). If the harmonic signal falls within the passband of a receiver within the same (or a nearby) device, and the signal level is of sufficient amplitude, it will degrade the performance of the receiver.

Qualcomm analyzed the effect that the harmonics from 600 MHz equipment can have on the 3GPP band classes and other relevant North American frequency bands (shown in Table 1 below), for user equipment that operates in the frequency bands shown below are likely to be used for 600 MHz band operations.[13]

[13] Qualcomm's harmonic analysis involved measured results of commercial 750 MHz LTE power amplifiers up to the 9th harmonic.

Band (Service)	Uplink (MHz)		Downlink (MHz)		BW (MHz)	Tx-Rx (MHz)
2 (PCS)	1850	1910	1930	1990	60	80
4 (AWS-1)	1710	1755	2110	2155	45	400
5 (Cellular)	824	849	869	894	25	45
12 (Lower 700 MHz)	698	716	728	746	18	30
13 (Upper 700 MHz)	777	787	746	756	10	-31
14 (700 MHz D)	788	798	758	768	10	-30
17 (Lower 700 MHz)	704	716	734	746	12	30
23 (S Band)	2000	2020	2180	2200	20	180
25 (PCS + G)	1850	1915	1930	1995	65	80
41 (BRS/EBS)	2496	2690	2496	2690	194	
TV Chs 55&56			716	728	12	
Public Safety			769	775	6	
3.5 GHz	3550	3650	3550	3650	100	
WCS	2305	2320	2345	2360	15	40
600 MHz	500	698	500	698	198	
2.4 GHz	2400	2484	2400	2484	84	
5 GHz	5170	5330	5170	5330	160	
	5490	5835	5490	5835	345	
	5850	5920	5850	5920	70	
900 MHz	902	928	902	928	26	
GNSS L1			1559.052	1605.886	46.834	
GNSS L2			1226.577	1249.136	22.559	
GNSS L5			1164.45	1188.45	24	

Table 1. North American Victim Receive Bands That Were Analyzed

All of the North American bands listed in Table 1 above that can be affected by 600 MHz band signal harmonics are identified below in Table 2. There are mobile, unlicensed Wi-Fi, and positioning receive bands that may be potentially jammed by harmonics of 600 MHz uplink operations in each of the 24 analysis blocks.[14] Wi-Fi and positioning are relevant to the analysis because currently available consumer devices allow multiple physical layers to be active concurrently. This analysis shows that a third order harmonic from 600 MHz operations in

[14] By way of example, the 2nd harmonic of Band 13 uplink operations falls very close to GPS, which introduced significant design issues. Band 14 uplink operations also have serious GPS issues. Thus, placing uplink operations that generate harmonic energy in a GNSS band is a serious issue.

analysis blocks 14 through 18 (*i.e.*, "H3" in Table 2) may jam the PCS receive band. A more powerful second order harmonic from 600 MHz operations in analysis blocks 1 to 4 and 8 to 10 ("H2" in Table 2) may jam the Global Navigation Satellite System ("GNSS") positioning receivers that operate within 1164.45 to 1188.45 MHz and 1226.577 to 1249.136 MHz.[15]

The top 5 analysis blocks (*i.e.*, analysis blocks 20 through 24 — the 25 MHz which runs from 673 to 698 MHz), have one potential victim: a substantially lower power 8th order harmonic generated by uplink transmissions between 673 to 698 MHz that may impact unlicensed operations at 5 GHz. Uplink transmissions in analysis block 19, specifically a fourth order harmonic, can impact BRS/EBS (Band 41) operations in the 2.5 GHz band. Based on this analysis, Qualcomm believes that the upper portion of the 600 MHz band, specifically the 25 MHz-wide band comprised of analysis blocks 20 to 24, is best suited to support mobile broadband uplink operations.[16]

---

[15] Lower order harmonics are higher in power, and typically require substantial duplexer attenuation to meet the 3GPP general out-of band emissions level of -30dBm/MHz EIRP.

[16] Qualcomm also analyzed the impact of 600 MHz harmonics on bands in use outside North America. Not surprisingly, the total number of affected bands increased from 9 (as shown in Table 2) to 26. With regard to analysis blocks 20 to 24, the analysis of non-North American bands showed that band class 34 (2010-2025 MHz TDD) and band class 42 (3400-3600 MHz TDD) may be impacted by third-order harmonics generated within analysis blocks 19 & 20 and by fifth-order harmonics generated within analysis blocks 20 to 24, respectively.

Analysis Block	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Victim Band																								
B2 (PCS)														H3	H3	H3	H3	H3						
B25 (PCS+G)														H3	H3	H3	H3	H3						
B41 (BRS/EBS)										H4	H4	H4	H4	H4	H4	H4	H4	H4	H4					
GNSS L2								H2	H2	H2														
2.4 GHz					H4	H4	H4	H4	H4															
3.5 GHz			H6	H6	H6	H6	H6																	
WCS		H4	H4																					
5 GHz	H9	H9	H9	H9	H9	H9	H9	H9	H9	H9	H9	H9	H9	H8 H9	H8 H9	H8 H9	H8	H8	H8	H8	H8	H8	H8	H8
GNSS L5	H2	H2	H2	H2																				

Table 2. North American Victim Receive Bands Potentially Affected By 600 MHz Operations

Qualcomm also analyzed the potential intermodulation distortion ("IMD") that 600 MHz operations may create within a user device. IMD is generated where the modulation of signals at two (or more) different frequencies in a system with nonlinearities (such as a smartphone or tablet device) combine to form unwanted additional signals at frequencies that not only appear at the harmonics (integer multiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies. This analysis considered the impact potential of the combination of transmit and receive harmonics to create spurious responses.[17]

[17] Qualcomm's analysis assumed the filter attenuation of the harmonics to be 40 dB and considered the first 9 harmonics of the transmitter and first 5 harmonics of the transceiver's local oscillator ("LO"). Typical levels of transmit harmonic power and typical levels of receive harmonic response were used to categorize the severity of the various spurious responses. Those above -60 dB may be considered very severe, and those above -80 may be considered severe; levels between -80 and -100 dB are less severe, but may still be problematic.

Figure 2 below shows the number of intermodulation spurs greater than -60, -80, and -100 dBm in each of the 24 5 MHz analysis blocks. Figure 2 confirms the harmonic analysis presented above. The lower portion of the band is a particularly poor swath of spectrum in which to place 600 MHz uplink operations. Therefore, uplink operations should be kept in the upper portion of the spectrum band, specifically within analysis blocks 20 to 24 or from 672 to 698 MHz.[18] The impending launch of carrier aggregation technology, whereby carriers bind one LTE band to another to create wider channels to support enhanced service, would be adversely impacted by uplink operations below 672 MHz.

This analysis further confirms the above finding that the top five 5 MHz analysis blocks are the best choices in the band to support uplink operations and that uplink operations in the first 19 analysis blocks introduces significant potential for interference.

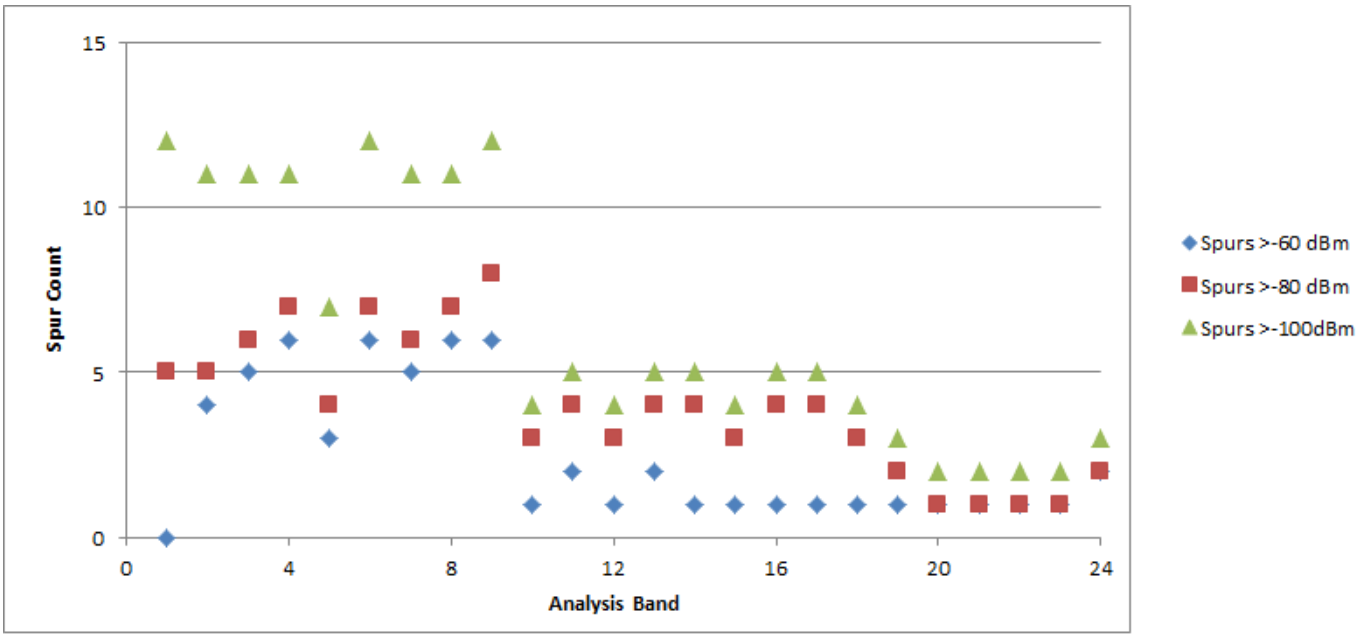

Figure 2. Intermodulation Spurious Analysis Results for the Twenty-Four 5 MHz Analysis Blocks

[18] There is a potential issue caused by analysis block 24 to 3GPP Band Class 5, but otherwise analysis blocks 20-24 are still pretty clear for North American operators. However, all five bands may potentially jam 900 MHz unlicensed Wi-Fi operations in the same device.

Qualcomm's analysis of the harmonic and IMD spurious interference are based on typical measurements and a determination of whether the interferer falls within a victim receive band. The potential contributions of the receiver low noise amplifier ("LNA"), LO and mixer were considered jointly, which means that the overall system response was considered.

B. Measurement Of Currently Available Antenna Technology Indicates That Single Antenna System Support Of A 62 MHz Passband for 600 MHz FDD Operations Is Challenging But Technically Possible

Qualcomm also analyzed the antennas that could be used to support operations in the 600 MHz band and believes that it is particularly important that the paired operations within the band be supported by a single antenna system, preferably the same antenna system already currently used in smartphones that support operations at 700 MHz. Today's mobile devices are extremely space constrained. It is fair to say that there is no spare space in today's smartphones. Adding a new low frequency band requires that either a relatively large antenna system be added or an existing antenna (such as that used to support Band 12, 17, or 13 in the 700 MHz band) be tuned to operate in the lower frequency band. By way of example, an antenna that is designed exclusively to support 600 MHz operations could require approximately 60% more volume than current 700 MHz antennas, which would substantially challenge current smartphone form factors. In other words, we are concerned that if the Commission's band plan requires use of a separate antenna system for 600 MHz, smartphones would have to become much larger in order to perform acceptably.

For a given device type that has a defined antenna volume and frequency of operation, there is a percentage bandwidth for which the desired efficiency can be achieved. A specific antenna efficiency (*i.e.*, gain) is a requirement for every concurrently active band, where both transmit and receive, *i.e.*, the real time or instantaneous antenna bandwidth, can be active on the

same device.[19] The theoretical peak efficiency for an antenna with a constant volume varies as $1/f^3$, as depicted in Figure 3.

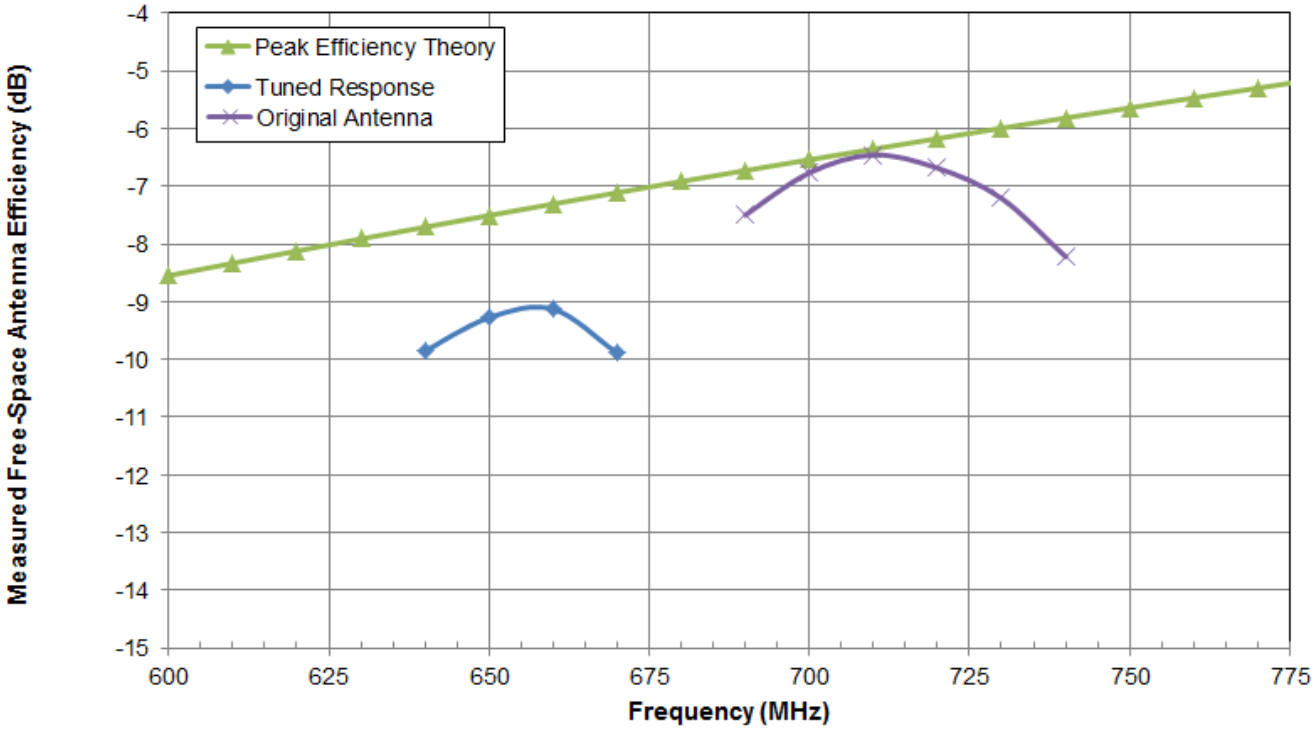

Figure 3. The Impact of Tuning a Fixed Volume 700 MHz Antenna to the 600 MHz Band

Thus, Qualcomm found that a currently implemented 700 MHz band antenna, *i.e.*, an antenna that achieves a 6% 1 dB efficiency bandwidth at 710 MHz, has its 1 dB efficiency bandwidth reduced to approximately 4.6 % when it is retuned to operate at 660 MHz. Qualcomm agrees with Ericsson and IWPC, cited by the Commission in the *NPRM*, that current mobile device filter technology, including surface acoustic wave ("SAW") filters using Lithium and Tantalum, is limited to a maximum passband of approximately 4% of the passband's center

[19] The reuse of the 700 MHz antenna system for 600 MHz operations likely prevents carrier aggregation with frequency bands below approximately 1.2 GHz.

frequency.[20] An FDD band plan that is 2 x 25 MHz with a ~12 MHz duplex gap is derived as the maximum bandwidth for a single duplexer implementation based on the ~4% maximum filter bandwidth limitation.

Further, given that uplink operations are best supported by the upper 25 MHz of the 600 MHz band, Qualcomm is concerned about the technical feasibility of a band plan that would allow Time Division Duplex ("TDD") operations in this band.[21] We are more confident about the technical feasibility of using the 600 MHz band for Frequency Division Duplex ("FDD") operations, that is, with 2 x 25 MHz situated in the uppermost portion of the band, as depicted in Figure 4 below; this is the optimal approach given the capabilities of the components currently available, specifically, antenna physics, duplexer, and filter technology. Qualcomm believes that a duplex gap of approximately 12 MHz can offer improved duplexer performance.

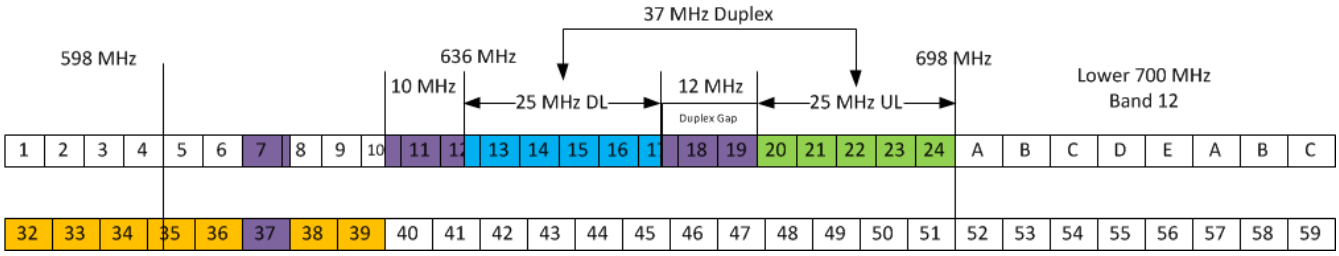

Figure 4. 600 MHz Band Plan where 72 MHz is Recovered for Flexible Use Purposes

As discussed in the following section, in areas of the country where additional TV broadcast spectrum is recovered, that spectrum should be used to support SDL operations, as uplink signals in other portions of the 600 MHz band may jam many other bands (particularly those shown in Figure 2 above).

---

20 *See Incentive Auction NPRM* at n.250.

21 *See Incentive Auction NPRM* at ¶¶ 183-84.

C. In Areas Where The FCC Recovers More Than 72 MHz of Spectrum, The Extra Spectrum Should Be Auctioned Off For Supplemental Downlink Use

In those areas of the country where the FCC recovers more than 72 MHz of spectrum below 698 MHz, the FCC should auction that additional spectrum for SDL use.[22] Indeed, wireless carriers would put this spectrum to good use, for mobile broadband traffic data shows that the ratio of downlink to uplink can be 10:1 or greater.[23]

Figure 5 below shows a band plan that could be used in those areas where TV broadcast channels 32 through 51 are cleared (with the exception of Channel 37, which is left as is). To the extent that fewer channels are repurposed for mobile broadband operations, less SDL spectrum would be auctioned. And, as the Commission notes, by placing SDL spectrum blocks adjacent to the FDD downlink portion of the band, there is no need to provide for guard bands between those downlink blocks.[24] Similarly, there is no need to provide a guard band between the 600 MHz uplink band and the Lower 700 MHz uplink band, specifically, the Lower 700 MHz A Block, for like operations in directly adjacent bands are spectrally compatible.[25]

---

22 *See Incentive Auction NPRM* at ¶ 134 (seeking comment on the extent to which mobile broadband traffic today is asymmetrical).

23 *See, e.g.*, Hossein Falaki, *et al*. "A First Look at Traffic on Smartphones" IMC 2010 Melbourne (Nov. 2010) (uplink traffic volume measured to be more than 10 times the downlink traffic for certain users, with a average uplink to downlink ratio of 6:1).

24 *See Incentive Auction NPRM* at ¶ 135.

25 *See Incentive Auction NPRM* at ¶ 154.

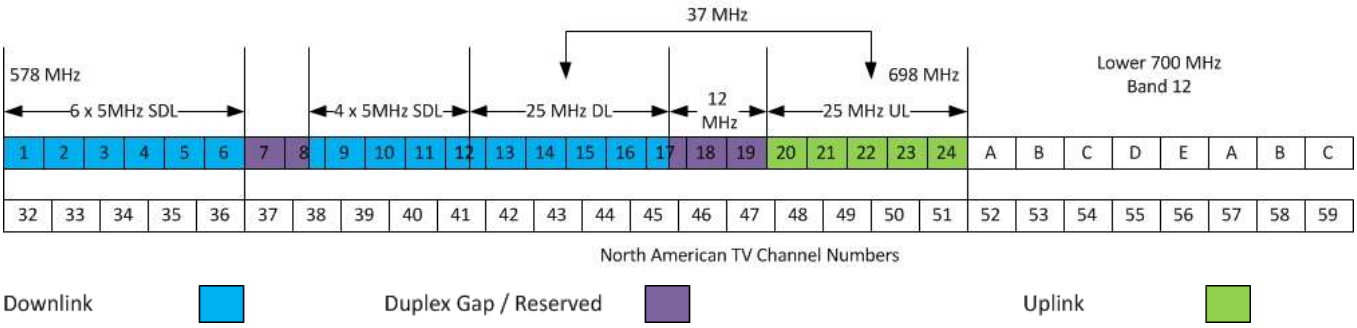

Figure 5. Potential 600 MHz Band Plan where 19 TV Broadcast Channels are Repurposed

Qualcomm expects SDL technology to create opportunities in the U.S. and around the world in markets where wireless carriers can use unpaired spectrum bands in conjunction with their existing paired bands to substantially improve mobile broadband data download performance. As described above, the asymmetry of mobile broadband data demand makes the use of SDL appealing, and it is unquestionably spectrally efficient. In fact, AT&T intends to deploy SDL technology using the Lower 700 MHz spectrum that it acquired from Qualcomm and plans to integrate the technology into its longer-term LTE network plans.[26]

For the reasons explained above, Qualcomm is concerned that creating additional FDD pairs in any portion of the lower nineteen analysis blocks would not be a successful arrangement. Doing so would create a stark disparity between the lower FDD pairs and the FDD pairings at the upper end of the 600 MHz band that do not cause interference to other bands that may be in simultaneous use on the device. Accordingly, Qualcomm cannot agree more that the lessons learned from the 700 MHz band plan design include the need to "make the 600 MHz spectrum

---

[26] See Qualcomm Announces Agreement for Sale of 700 MHz Spectrum Licenses (Dec. 20, 2010) *available at* http://www.qualcomm.com/news/releases/2010/12/20/qualcomm-announces-agreement-sale-700-mhz-spectrum-licenses. *See also AT&T Agrees to Acquire Wireless Spectrum from Qualcomm, Spectrum To Help AT&T Continue To Enhance The Mobile Broadband Experience Nationwide* (Dec. 20, 2010) *available at* http://www.qualcomm.com/news/releases/2010/12/20/att-agrees-acquire-wireless-spectrum-qualcomm.

blocks as similar and technically interchangeable as possible to allow for enhanced substitutability across blocks[,] allow for greater flexibility in [] auction design choices,"[27] and enable the highest level of participation in and proceeds from the forward auction.

D. In Areas Where The FCC Recovers Less Than 72 MHz of Spectrum, It Can Maintain The Same 25 MHz Downlink Band But Permit Low-Power TV Operations Close To The Uplink With An Appropriate Guard Band

Qualcomm much prefers a national band plan that frees up as much spectrum as possible for mobile broadband in a band plan along the lines of what is described herein. Every effort should be made to accomplish this both through plain repacking and through the auction and subsequent repacking. However, Qualcomm realizes that it may not be possible to create a national band plan if there are particular regions (such as border areas with Canada and Mexico) where significantly less spectrum is freed up.

Thus, in those areas where the FCC recovers less than 72 MHz of spectrum, the agency should maintain the same 25 MHz downlink band (if possible), and permit TV operations (preferably low-power TV) close to the uplink. To avoid interference to mobile devices, the TV channel(s) need to be contained inside the national 25 MHz uplink band, and it is also important to maintain appropriate guard bands to protect mobile broadband operations in both the 600 MHz downlink and uplink bands. This could be accomplished as follows: Locate the TV channel(s) below the 600 MHz uplink bands in order to lessen the IMD product created by the TV station and uplink operations that potentially impacts the FDD downlink band.[28] Provide at least 6 MHz

---

[27] *See Incentive Auction NPRM* at ¶ 151 (citing Service Rules for the 746-764 and 776-794 MHz Bands, WT Docket No. 06-150, *Report and Order and Further Notice of Proposed Rulemaking*, 22 FCC Rcd 8064 (2007).

[28] The TV station in the duplex gap can be in the unfortunate (Tx + Rx)/2 location and thus create an IMD product with the FDD uplink band that falls directly within the downlink of the FDD band, causing desense in the mobile device. This is another reason why TV operation in the duplex gap is a serious problem and why Qualcomm recommends that any such TV stations

separation between the TV channel(s) and the uplink band in order to avoid the uplink channel from being immediately adjacent to the TV station and thus avoid issues similar to those currently impacting the Lower 700 MHz A block — the so-called Channel 51 problem. And finally, make sure the TV channel is contained inside the national 25 MHz uplink band; this will provide strong attenuation of the TV signal from the duplexer's downlink band filter and offer protection of the downlink receive path.

By way of example, consider the 2 x 25 MHz FDD plan shown above in Figures 4 and 5. If less than 72 MHz is cleared, a 10 MHz LTE uplink channel may be supported within the top 12 MHz of the FDD uplink band and TV channel 48 could remain. And, if less spectrum is cleared so that at most a 5 MHz LTE channel can be provided in the topmost 6 MHz of the FDD band, then TV channels 48 and 49 could remain. Thus, in these scenarios, 5 or 10 MHz of uplink is supported as opposed to the full 25 MHz.[29]

While Qualcomm recognizes that this is a sub-optimal approach, it is consistent with the FCC's goal of "keeping the downlink spectrum consistent nationwide, [so it] can help ensure as a technical matter that wireless providers will be able to offer mobile devices that can operate across the country, which should minimize device cost and interoperability concerns, and allow for greater economies of scale."[30]

---

be low power. The suggested location and power of the TV channels is to minimize the IMD product that is generated in the mobile device. However, even this does not eliminate the potential for desense.

[29] If, for example, the FCC were to adopt a 2 x 30MHz FDD plan (which as explained herein has technical challenges) and not enough TV channels are recovered to provide a full 30 MHz uplink, a 10MHz LTE channel may be supported in top 12 MHz of the FDD uplink band, and TV channels 47 and 48 could remain. And, if only a 5MHz LTE channel could be supported in the top 6 MHz of the FDD uplink band, TV channels 47, 48 and 49 could remain.

[30] *Incentive Auction NPRM* ¶ 124.

Finally, and while it would be unfortunate were this to occur, in areas where minimal spectrum usage rights are reclaimed even after repacking the band, *e.g.*, 6 or 12 MHz, the Commission should not clear any channels in that market — with the exception of Channel 51 in order to relieve interference to Lower 700 MHz A block licensees — and instead work to enable as much flexible use spectrum in all other areas of the country.[31] It is important that whether or not the Commission is able to close an incentive auction, under any and all circumstances, the Channel 51 problem must be eliminated via repacking.

E. The FCC Should Endeavor To Define A Band Plan Where 2 x 5 MHz Paired Spectrum And 5 MHz SDL Blocks Are Spectrally Identical And Thus Fungible

As Qualcomm describes in these Comments, in order for the incentive auction process to be successful, the FCC may have to define a band plan that is flexible to accommodate the recovery of different amounts of spectrum in different regions of the country, if it is not possible to implement a national band plan (which is unquestionably the most desired approach). Given that the spectrum blocks to made available for FDD operations will be generic blocks (and not specific frequency blocks),[32] for the auction to be successful, each 2 x 5 MHz FDD block should be spectrally identical to each other, which requires the FCC to incorporate sufficient guard bands so that the spectrum blocks adjacent to the guard bands are protected the same as the non-adjacent spectrum blocks.[33] Similarly, the 5 MHz blocks that are identified and auctioned for

---

31 *See Incentive Auction NPRM* at n.209.

32 *See Incentive Auction NPRM* at ¶ 56 (where there are multiple blocks of spectrum available in a geographic area, … we could collect bids for one or more "generic" categories of licenses, such as paired or unpaired licenses, in a geographic area. Rather than indicating that a bid is for a specific frequency block in an area, bidders would indicate their interest in, for example, one or more paired 5 megahertz uplink and 5 megahertz downlink (5 +5) blocks.").

33 *Cf* Promoting Interoperability in the 700 MHz Commercial Spectrum, *Notice of Proposed Rulemaking*, ¶¶ 5, 32, WT Docket No. 12-69, RM-11592 (rel. Mar. 21, 2012). *See also Incentive Auction NPRM* at ¶ 173.

SDL use also should be spectrally identical to each other, which is accomplished by providing sufficient guard bands to protect the downlink bands from TV broadcast operations and other incompatible services.[34] In this regard, Qualcomm recommends that there be a separation of approximately 10 MHz between the highest full power TV station and any downlink block to avoid saturation of the receiver in the user device. If the last TV station abutting the first SDL block is a low power TV station, it should be possible to reduce the required frequency separation.

If the FCC recovers spectrum down to TV channels 36 or 38, 6 MHz of that separation could be provided by Channel 37, on which the existing WMTS and radio astronomy operations could continue. In that case, the actual guard band could be greatly reduced to approximately 3 MHz.[35] One such scenario is shown in Figure 6 below where Channels 38 and above are repurposed; in this case, there would be an 11 MHz duplex gap.

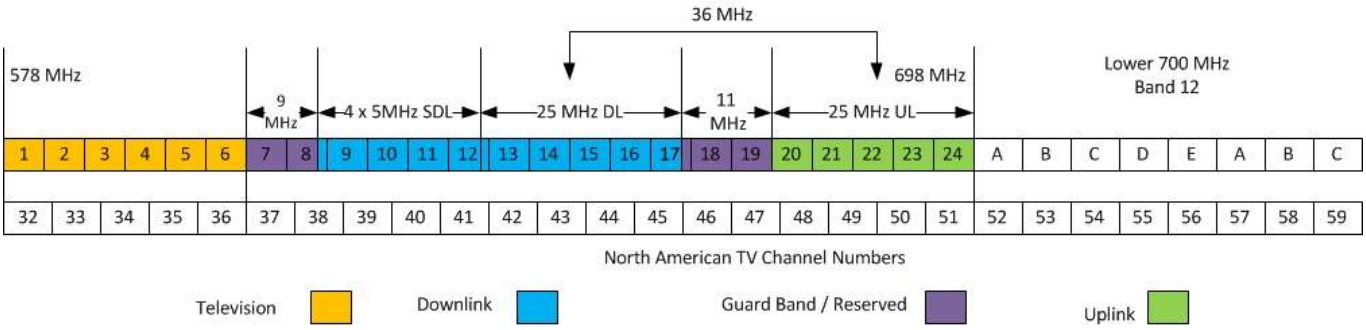

Figure 6. Potential 600 MHz Band Plan where Channel 37 Is Used As A Guard Band

Moreover, when the FCC assigns spectrum to winning bidders post auction, it should assign spectrum in contiguous blocks if a single bidder wins 2 x 10 MHz FDD blocks or two

34 *See Incentive Auction NPRM* at ¶ 64.

35 *See Incentive Auction NPRM* at ¶ 153.

5 MHz supplemental downlink bands. This would allow these bidders to deploy wider bandwidth LTE systems, which enhance efficiency.

As Qualcomm has explained above, not all band plans lend themselves to being readily incorporated into today's smartphones and tablets without increasing the cost, form factor, and battery power needs of those devices. Sub-optimal band plans not only are likely to lead to lower offers from potential forward auction bidders, but they also require the incorporation of additional filters, duplexers, tuners, antennas, and switches, which increases device size and cost and likely will decrease device attractiveness to consumers. A successful band plan design is one that could be readily incorporated into mobile devices that are comparable in size and function to the devices that consumers are so heavily using today. This will enable service providers to timely deploy services and equipment that make full use of the spectrum and, like today's devices, support simultaneous operations in multiple bands. This approach will enable the 600 MHz forward auction to become the FCC's most successful auction ever on a $/MHz/Pop basis.

F. Preliminary Analyses Show TV White Space Device Or Wireless Microphone Operations In The Guard Band Or Duplex Gap To Be Problematic

Qualcomm's preliminary analysis of whether TV white space devices or wireless microphones should be permitted to operate in the guard bands that separate TV broadcast channels from mobile broadband operations indicates that operation of TV white space devices or wireless microphones can cause interference to mobile devices operating in the directly adjacent bands.[36] Qualcomm's preliminary analysis also indicates that an LTE mobile device will interfere with TV white space devices. If further analysis confirms these findings, then the

[36] *See, e.g., Incentive Auction NPRM* at ¶¶ 221-26 (discussing wireless microphones) and at ¶¶ 227-38 (discussing TV white space devices).

mobile broadband spectrum blocks that are directly adjacent to the guard bands or the FDD duplex gap will not be spectrally equivalent — and thus not fungible — with the blocks located more than 5 MHz away from the guard band and duplex gap. Thus, Qualcomm would recommend that the guard bands and duplex gap remain clear of any such other operations.[37]

Qualcomm agrees with the FCC "that the Spectrum Act constrains the Commission to guard bands 'no larger than is technically reasonable to prevent harmful interference between licensed services outside the guard bands.'"[38] This is why Qualcomm continues to refine the recommendations in these comments to, among other things, enable the smallest possible guard band and duplex gap. Indeed, the Commission recognizes the need "to provide as much certainty about the operating environment as possible," and the concomitant need to "propose technical solutions to ensure that the spectrum blocks are as free from interference as possible."[39]

Should the Commission nonetheless decide to place some operations within the duplex gap or lower guard band, wireless microphones are greatly preferred over TV white space devices because wireless microphones are likely to pose less pervasive interference. As Qualcomm explained above, placing SDL operations in the duplex gap will require a wider duplex gap because of the guard band necessary to protect the uplink, and a wider duplex gap raises antenna issues and detracts from the total amount of usable paired spectrum.[40]

---

37 Indeed, a guard band is an unused part of the radio spectrum between disparate radio bands for the purpose of preventing interference between the bands.

38 *See Incentive Auction NPRM* at ¶ 126 (quoting the Spectrum Act § 6407(b)). In addition, it follows that any operations within guard bands themselves (such as TV white space devices and unlicensed devices) cannot cause interference to licensed services.

39 *See id.* at ¶ 125.

40 *See also* n.28, *supra*.

Additionally, Qualcomm believes the operations in Channel 37 can currently remain there,[41] but the FCC should consider moving the Channel 37 operations if it helps to enable the development of a nationwide band plan. As Qualcomm notes herein, Channel 37 can enable a smaller guard band separating TV broadcast operations from mobile broadband operations to the extent the bands to be made available for mobile broadband do not extend below Channel 37.

G. Qualcomm Generally Supports The FCC's Technical Proposals For Mobile Broadband Operations In The 600 MHz Band

Qualcomm supports the Commission's general approach of applying the technical rules for the Lower 700 MHz to the 600 MHz band.[42] For example, Qualcomm agrees with applying current FCC Rule Section 27.53(g) for out-of-band emissions attenuation of 43+10*log10(P) dB and the associated measurement procedure to the 600 MHz band.[43] And, should harmful interference occur, the FCC under Rule Section 27.53(i) can impose higher emissions limits as a remedy.[44] Qualcomm also supports the Commission's proposal to adopt a 3 W ERP power limit for both portables and mobiles, which presently applies to the Lower 700 MHz band.[45]

II. Qualcomm Supports Reverse Auction Bid Options For TV Broadcast Licensees Beyond Those Made Explicit In The Spectrum Act

Because it is critically important that the Commission recover as much spectrum for mobile broadband operations as possible via the incentive auction process, Qualcomm strongly supports the development of options for reverse auction bids beyond those explicitly included in the Spectrum Act, including allowing bids by TV broadcast licensees to voluntarily accept

41 *See Incentive Auction NPRM* at ¶ 212

42 *See Incentive Auction NPRM* at ¶ 185.

43 *See id.* at ¶ 187.

44 *See id.* at ¶ 190.

45 *See id.* at ¶ 194.

additional interference.[46] If a single TV broadcast licensee agrees to receive payment for accepting interference due to mobile broadband operations in an adjacent market, it could enable the release of additional spectrum in not just one but several adjacent markets.

In a similar vein, Qualcomm agrees that the FCC should adopt a policy favoring grant of post-incentive auction requests for waivers of the VHF power and height limits for any winning UHF to VHF bidders that experience unusual coverage problems on their new VHF channels in order to encourage UHF to VHF bids.[47] In order to facilitate its ability to clear high VHF channels for repacking purposes, the FCC also should permit eligible TV Broadcast licensees to participate in the auction by agreeing to relinquish a high VHF channel for a low VHF channel.[48]

Finally, Qualcomm also supports allowing eligible TV broadcast licensees to participate in the auction by agreeing to reduce their service areas, accept additional interference from other TV stations, and/or reduce their population coverage.[49] Doing so will provide the FCC with additional flexibility to enable the reverse auction to free up as much spectrum for mobile broadband as possible.

---

46 *See Incentive Auction NPRM* at ¶ 9.

47 *See Incentive Auction NPRM* at ¶ 85 (Noting that the FCC granted such waivers following the conclusion of the full power television digital transition in 2009 to help stations on post-transition VHF channels resolve reception issues).

48 *See id.* at ¶ 86.

49 *See id.* at ¶ 86.

CONCLUSION

Qualcomm is pleased to provide the foregoing comments on the *Incentive Auction NPRM*. As the FCC appropriately recognizes, mobile broadband spectrum is the lifeblood of today's information economy and America's present and future economic success, for such spectrum is essential to enabling "a high-performance America — a more productive, creative, efficient America in which affordable broadband is available everywhere and everyone has the means and skills to use valuable broadband applications."[50] We look forward to continuing our work with the Commission and our industry partners to define a band plan at 600 MHz that can best support mobile broadband operations and continue to fuel the remarkable mobile broadband ecosystem.

Respectfully submitted,

QUALCOMM INCORPORATED

By: _____

Dean R. Brenner
Senior Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

Attorneys for QUALCOMM Incorporated

Dated: January 25, 2013

[50] FCC National Broadband Plan (Mar. 16, 2010) at 9.